

Study on optimizing the built environment of universities guided by disaster resilience theory

Jiageng Wang

*School of Architecture, North China University of Water Resources and Electric Power, Zhengzhou, Henan, 450046, China
w18272586913@163.com*

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Abstract: The threats and challenges of climate change and public health and safety hazards have made the optimal construction of habitat a hot topic, and the resilience of habitat has gradually become a hot topic of concern for academics and the public. The study investigated the current situation of resilience construction in some university campuses in the Central Plains region. The preliminary evaluation index system model of the resilience of university built environment was compiled. The study provides research inspiration for the resilience enhancement of the built environment of universities in a universal way.

1. Introduction

The changing global climate and a surge in the instability of public health and safety hazards have led to a general increase in the probability of disasters. Climate change-induced disasters (floods, heavy rainfall, droughts, extreme heat and storms) have caused more than 7,500 disasters worldwide in the last 20 years, resulting in more than 250 million casualties and economic losses of US\$2 trillion. Public health and safety hazards have also become a major cause of disasters, especially in the context of today's global new coronavirus epidemic, and their impact on the world has gone beyond the past. The habitat as a complex adaptive system has become a hot topic of research on how to maintain system stability in the face of risk.

The significance of optimising the construction of the existing habitat environment on university campuses is not only reflected in the enhancement of the resilience of universities and the protection of the lives and property of teachers and students, but is also inseparable from the sustainable development and social responsibility of universities. As an important educational, scientific research and social service institution, it is increasingly important for universities to build an environment that enhances the resilience of construction and optimises a green, healthy and safe living environment.[1] It becomes more and more important.

2. Threats and challenges to the built environment of universities

2.1 Impacts from climate change

The unstable risk factors arising from climate change pose many challenges to the built

environment. The frequent occurrence of extreme weather events such as heavy rainfall, floods, droughts and snowstorms, and extreme weather events pose serious challenges to the stability and safety of university buildings, facilities, transport and other infrastructure; climate change affects the ecological environment (vegetation cover, water reserves) within the university campus, and these environmental changes will have a direct impact on the health and quality of life of university staff. These changes will have a direct impact on the health and quality of life of the students. The building structures, materials and equipment of our universities have a certain level of resilience to disasters, but these facilities often have difficulty withstanding sudden shocks during extreme weather events. On 20 July 2021, the city of Zhengzhou was hit by an exceptionally heavy rainstorm, and the rain and flooding brought about by the strong convective weather posed a great threat to the safety of people's lives and property and social stability in the city and on campus; the heavy rainfall in Changsha in July 2016 caused damage to many buildings such as the library and laboratory building of Hunan Normal University, many of which have reached the standard of "thin building". Many of these buildings have reached the standard of "thin buildings". Climate change has accelerated the urban heat island effect, and environmental factors such as indoor temperature and humidity in university buildings will be affected. Research has shown that the impact of the urban heat island effect on university buildings varies from place to place, and that overall, changes in indoor temperature and humidity will affect the learning, productivity and health of students and staff. In addition, flooding caused by climate change will also pose a threat to the built environment of universities to varying degrees. Resilience in the built environment of universities is imperative.

2.2 Challenges posed by public health and safety hazards

Public health and safety is another crucial issue facing the construction of university habitats, especially in the built environment of universities. In recent years, outbreaks of public health events such as the New Crown epidemic have attracted significant global attention. As of 26 May 2023, the New Coronation epidemic has resulted in a cumulative total of 766,440,032 confirmed cases and 6,932,578 cumulative deaths worldwide. Against this backdrop, the public health and safety of the built environment of universities is also receiving increasing attention.

The main public health and safety risks in the built environment of higher education come from intensive contact between people such as students, staff and visitors. Students live in centrally-located areas and share public facilities with others, such as canteens, libraries and bathrooms, which can easily become breeding grounds for the spread of viruses. Furthermore, the high population density and mobility in the built environment of universities increases the risk of disease transmission in these areas. In addition, environmental pollution and food safety issues likewise pose certain public health and safety risks to the built environment of the campus.

3. Overview related to building resilience in the built environment of universities

3.1 Definition and characteristics of the built environment in universities

The built environment of higher education institutions refers to the comprehensive system consisting of buildings, facilities, sites, gardens, landscapes and surrounding areas of higher education institutions. The built environment is an important carrier and infrastructure for teaching, research, talent training and social services, and its quality and efficiency are directly related to the development level and social image of universities.[2] The quality and efficiency are directly related to the development level and social image of universities.

The built environment of universities covers a wide range of areas, including teaching buildings, laboratories, libraries, gymnasiums, canteens, dormitories and other buildings, as well as various

living facilities and transportation facilities; the built environment of universities is used intensively, with a large number of teachers, students and employees moving, studying, working and living on campus every day, which places higher demands on the management and maintenance of the environment. In addition, the built environment of universities is also highly innovative and open. As a place for higher education, university campuses provide students with a complex environment conducive to knowledge innovation and exchange of ideas, which makes the built environment of universities more complex and changeable. Therefore, the resilience of the built environment of universities is an important measure to ensure the sustainable development of universities, and it is also an urgent problem to be solved in the current construction of universities.

3.2 Connotations of resilience in the built environment of universities

The term 'resilience' in resilience theory has been defined in different ways in different fields of study[3] [4] In 1973, the American ecologist C.S. Holling[5] The idea of resilience was first applied to the study of ecosystem resilience to define the ability of an ecosystem to maintain a stable state.[6] In 1973, the American ecologist C.S. Holling first applied the idea of resilience to the study of ecosystem resilience to define the ability of an ecosystem to maintain a stable state. Subsequent research on resilience theory in urban and rural habitat construction has yielded rich academic results, with Yung Chi and Lai Tien[7] Zeng Suiping and others proposed that the resilience of university communities consists of five components: digital resilience, organisational resilience, spatial resilience, governance resilience and cultural resilience.[8] Zeng Suiping and others proposed the construction and governance of a resilient campus from an innovative ecological perspective with four dimensions: ecological, institutional, technological and facility (Figure 1); Jiang Limin[1,9] Jiang Limin proposed five dimensions of resilient campus planning (Figure 2). Based on the previous understanding of campus resilience, the built environment of colleges and universities is to enhance the resilience of the disaster-adapted built environment from three stages of disaster occurrence: resisting, adapting and recovering, so as to improve the overall immunity of the campus in the face of sudden disaster threats.

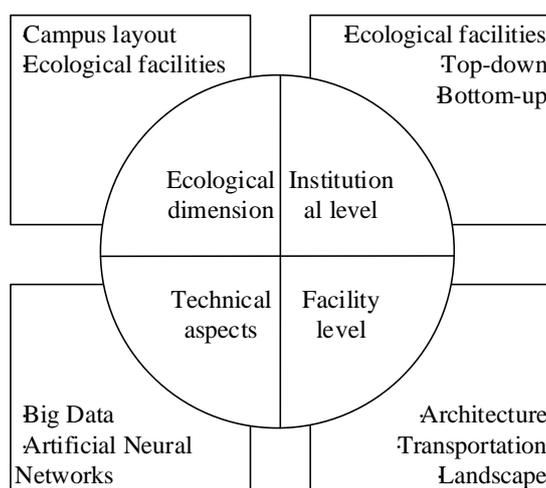


Figure 1: The connotations of the concept of resilience on campus

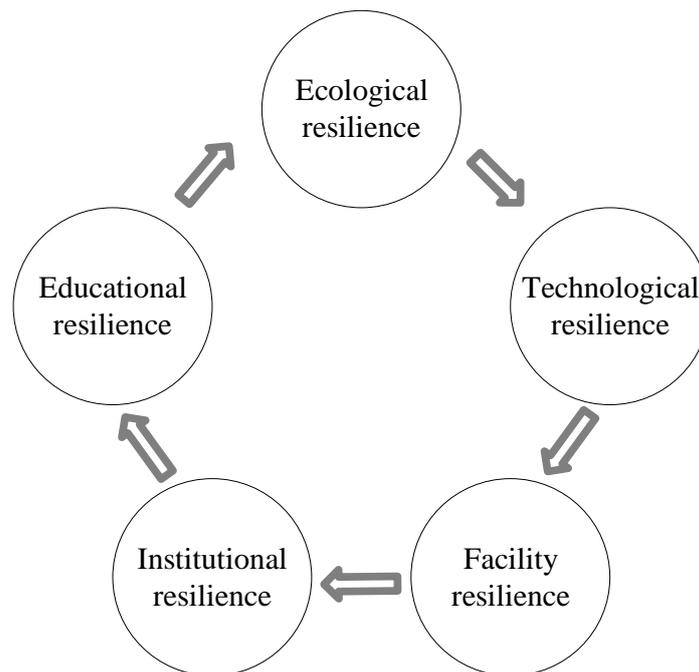


Figure 2: Five dimensions of campus resilience

3.3 Purpose and significance of the research on resilience building in the built environment of universities

3.3.1 Purpose of the study on resilience building in the built environment of universities

On the premise of ensuring the normal operation of university campuses, the built environment of university campuses should have the ability to enhance its resilience against natural disasters and man-made damage, and improve the adaptability, anti-disturbance and resilience of the campus environment by optimising the institutional facilities on campus in order to cope with the impact of natural or man-made security risks and hazards. By building a campus environment with high resilience, it can effectively prevent and reduce disaster losses, safeguard people's lives and property, and at the same time enhance the resilience of the campus resilience system in response to emergencies and improve the social influence and competitiveness of universities.

3.3.2 Research implications of resilience building in the built environment of universities

The resilience of the built environment of universities is important for ensuring campus safety, maintaining the physical and mental health of teachers and students, and improving the quality of teaching and research. In the face of emergencies, the resilience of the built environment of universities determines the resilience and recovery capacity of the campus. The resilience of the built environment of universities is an important guarantee for the sustainable development of universities.

Specifically, the resilience of the built environment of universities means that the design of buildings and infrastructures should take into account the various natural and man-made disasters that may be suffered, and take appropriate measures to improve and strengthen them, so as to minimise the damage caused by disasters. At the same time, the resilience of the built environment of universities also includes the full consideration of all resources such as personnel, materials and information, the establishment of comprehensive emergency plans and management mechanisms, and the improvement of the ability and efficiency to respond to emergencies. These measures can not only reduce disaster losses when emergencies occur, but also improve the efficiency and safety of

universities in their daily operations, providing a strong guarantee for their development.

4. Research and analysis of the current state of resilience building in the built environment of universities

4.1 Research on the built environment of universities

Table 1: Catalogue of university research

Research area	New Campus of Zhengzhou University
	Longzihu Campus, Henan University
	Jinming Campus, Henan University
	Henan University Minglun Campus
	Henan University of Technology Science Campus
	Longzihu Campus, Henan Agricultural University
	Longzihu Campus, North China University of Water Resources and Electric Power
	Garden Campus, North China University of Water Resources and Electric Power
	Henan University of Chinese Medicine
	Xinlian College of Henan Normal University

In order to study the current research prospects of resilience building in the built environment of universities, a detailed field study of the targets was required. Ten university campuses in the Central Plains region, mainly in Zhengzhou City, were selected (Table 1), and these target sites were comprehensively investigated in terms of campus landscape design, building structure, road planning and energy use. In terms of campus landscape design, issues such as campus greening, ecological wetlands and rainwater collection and utilisation were investigated; in terms of building facilities, issues such as ventilation, seismic resistance, fire prevention and drainage were investigated; in terms of road planning, the inadequacy of road foundation planning, road drainage and other issues were investigated, and the current problems in campus road planning were analysed. Through the above research contents, the problems of the built environment resilience construction of universities are summarized (Table 2)

Table 2: Summary of research questions on building resilience in the built environment in universities

The current state of resilience building in the built environment of higher education institutions	Poor adaptation to climate change and problems with lack of flood and fire protection measures;
	Inadequate awareness of disaster preparedness in schools and lack of targeted emergency plans and drills;
	Problems with the quality of buildings, lack of durability of building materials, lack of emergency supply facilities, etc;
	Poorly constructed campus space, inadequate road traffic planning and problems with poor access and flooding within the campus;
	Aging facilities and insufficient greenery have resulted in a less than aesthetically pleasing campus environment.

The resilience of the built environment is an important feature in ensuring that campuses remain operational during natural disasters, public health events and other emergencies. From the current state of the research, the resilience of the built environment of universities in China has yet to be

addressed. Energy wastage, water wastage, traffic congestion, low greening rates and inadequate foundation planning continue to plague the construction and operation of campuses. These problems lead to a lack of resilience in the campus environment and the threat of sudden disasters, which expose the buildings, facilities and people on campus to hazards and risks that are difficult to cope with and may cause serious damage to people and property.

4.2 The establishment of an index system for evaluating the resilience of the built environment of universities

In order to improve the resilience of the built environment on campus, a scientific assessment index system needs to be established to assess the level of disaster resilience of the built environment of universities. The selection of the indicators is based on academic research on resilient cities[10] resilient communities[11-14] and resilient campuses.[7-9,15,16] The indicators were selected with reference to the latest research results on resilient cities, resilient communities and resilient campuses, as well as field research on the built environment of university campuses (Table 2).

According to the campus resilience system proposed by Jiang Limin et al.[8,9] The first-level indicators of the evaluation index system of the built environment resilience of colleges and universities refer to the four dimensions of robustness, redundancy, efficiency and adaptability in the resilience theory, and the ecological resilience, facility resilience and technological resilience among the five indicators of campus resilience are selected, on the basis of which the second-level indicators are refined and the model of the evaluation index system of the built environment resilience of colleges and universities is established (Figure 3). The subsequent study will continue to optimize and improve it. Based on the establishment of the evaluation index system, the level of disaster resilience of the built environment of colleges and universities will be assessed through quantitative and qualitative analysis, and corresponding improvement plans will be formulated to improve the disaster resilience of the built environment of colleges and universities.

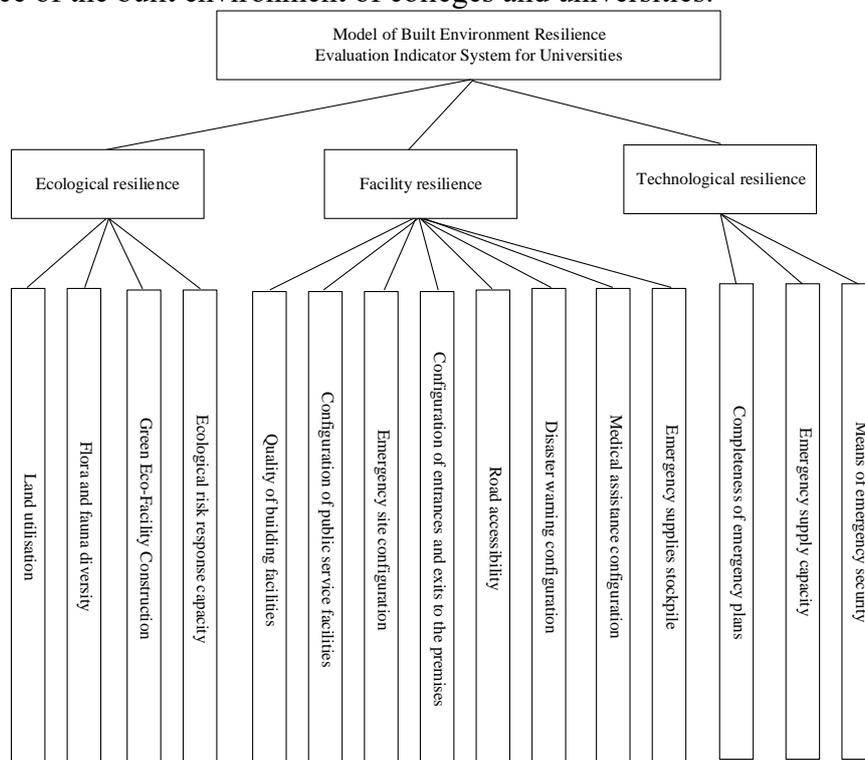


Figure 3: Model of the Built Environment Resilience Evaluation Indicator System for Universities

5. Strategies for optimising the resilience of the built environment in universities

Based on the current problems of the total price of the campus built environment research, combined with the evaluation index system of the built environment resilience of colleges and universities, the corresponding optimization construction is proposed for the resilience construction of the built environment of colleges and universities, starting from the ecological construction, building facilities and technical resilience of the built environment of the campus, and finally establishing a modern governance system of the built environment resilience of colleges and universities.

5.1 Optimising the ecology of the built environment on campus

5.1.1 Ecological planning and design

Optimising the ecological construction of the built environment on campus is an important task in maintaining the sustainable development of universities. The resilient construction of the built environment of universities should focus on protecting and restoring the ecological environment. In the planning stage of campus construction, the requirements of ecological protection and sustainability should be fully considered. This includes preserving and restoring natural ecosystems, rationalising the layout of green spaces and wetlands, optimising land use, and providing biodiversity conservation measures. Through scientific and rational planning and design, damage to the ecological environment can be minimised and a sound ecological foundation for the campus can be provided.

5.1.2 Green building and energy saving

Green building is one of the core elements of ecological construction, emphasising resource conservation, environmental friendliness and health and comfort of buildings. Renewable materials, energy-efficient equipment and green technologies are used in campus construction to reduce building energy consumption and carbon dioxide emissions. At the same time, designs such as natural lighting, ventilation and water recycling are introduced to improve the comfort and sustainability of the buildings.

5.2 Improvements to built facilities in the built environment on campus

5.2.1 Building facilities

The concepts and methods of disaster resilience theory can be applied to the design, construction and management of university buildings and facilities in order to improve the resilience of the built environment of universities and to ensure the safety and health of students and staff.

Building design needs to be taken into account building materials, structure and layout as a means of improving the building's resistance to earthquakes, fires and floods and to different types of disasters; in building structure design, flexible building materials can be used to increase the seismic performance of building structures; in building layout design, buildings can be divided into several independent modules to reduce the risk of the overall structure; integrate the concept of resilience into the university management system to manage these sites through disaster-adapted resilience theory to improve the safety and health of the facilities.

5.2.2 Traffic flow lines

The campus traffic flow aims to maximize accessibility and continuity, treating it as an integrated

system. It is essential to effectively distribute the main and secondary roads of the flow, while also considering the aesthetic aspects and practicality of the roads. Additionally, promoting sustainable and intelligent transport systems is crucial. Encouraging students, staff, and faculty to choose environmentally friendly modes of travel, such as walking, cycling, or public transportation, can be achieved by establishing a convenient network of walking and cycling paths. Ultimately, the goal is to establish a safe, comfortable, and easily accessible transport space.

5.3 Improving the technological resilience of the built environment on campus

5.3.1 Strengthening the campus network and information technology

Information technology in higher education is vital to improve the technological resilience of the built environment on campus. A high-speed and stable campus network is established to support the needs of teaching, research and management in all areas. At the same time, a comprehensive data centre and information management system is built to enable centralised management and sharing of information and improve the scientific and timely decision-making. Improve the efficiency and flexibility of campus operations and respond to various emergency and unexpected situations.

5.3.2 Strengthen the application of energy management and energy saving technologies.

Energy management is an important aspect of improving the technological resilience of the built environment on campus. By establishing a scientific energy management system (Figure 4), monitoring and controlling the consumption and use of energy on campus, taking effective energy saving measures, erecting intelligent lighting systems and energy-efficient building design to reduce energy consumption and carbon emissions. At the same time, renewable energy and energy storage technologies are introduced to improve the reliability and sustainability of energy supply and reduce reliance on traditional energy sources. Regularly inspect and maintain technical equipment. We need to update our technical equipment in line with the times and the changing needs of school staff.

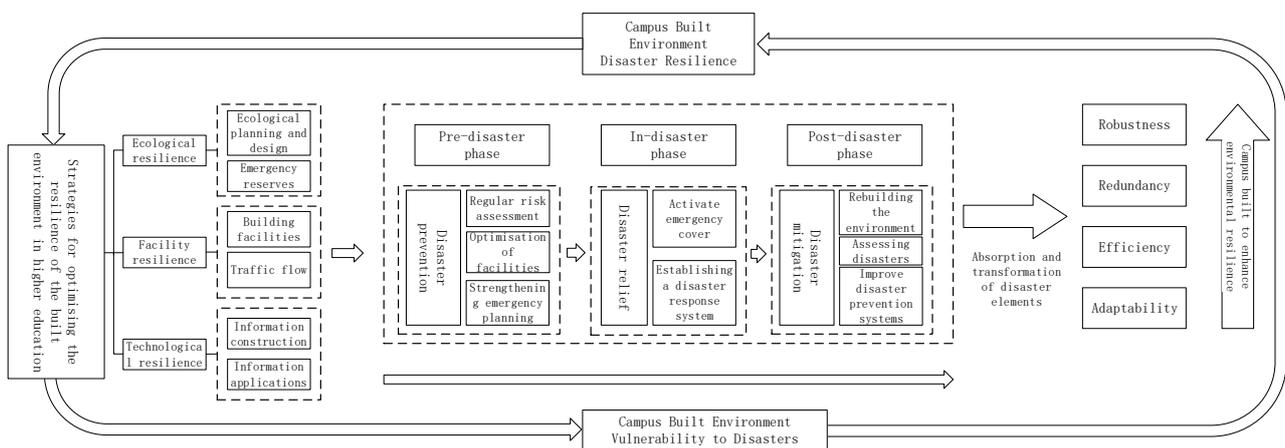


Figure 4: Campus built environmental resilience governance system

5.4 Establishing a governance system for the resilience of the built environment on campus

Establishing a resilient system for the built environment is a key step in ensuring that universities are able to respond effectively to disasters and other challenges, and to ensure the sustainability of the campus habitat. The ultimate goal of optimising the ecological construction of the built environment, improving the built facilities and enhancing the technological resilience of the built environment is to establish a scientific and rigorous system of governance for the resilience of the

built environment in universities (Figure 4). The planning and construction of the governance system is based on the three stages of disaster occurrence.

5.4.1 Pre-disaster phase

A comprehensive risk assessment of the internal campus environment needs to be conducted regularly. This assessment should identify natural and man-made risks that may affect the campus, such as epidemics, floods, fires, and others. There is a need to assess their potential threats and level of impact. Based on the results of the risk assessment, disaster response plans should be formulated. These plans should include the formation of emergency response teams, designation of responsible personnel, clarification of response measures, and deployment of resources.

Additionally, it is essential to strengthen the resilience of infrastructure and buildings on campus. This involves ensuring that campus buildings and facilities meet disaster resistance standards, including earthquake, fire, and water resistance. Efforts should be made to improve the structural safety of buildings and enhance the maintenance of facilities.

Furthermore, it is crucial to strengthen the stockpile of emergency materials. This includes preparing necessary emergency supplies and equipment, such as medical supplies, food, and emergency power generation equipment.

5.4.2 In-disaster phase

It is crucial to promptly activate emergency response mechanisms, organize rescue and evacuation operations, and prioritize the safety of individuals. Furthermore, it is essential to implement necessary emergency measures to urgently repair facilities, provide emergency supplies and medical treatment, and facilitate the evacuation of people to minimize disaster losses. Additionally, establishing a comprehensive disaster information monitoring and dissemination system is necessary. This system should enable the timely issuance of disaster and safety announcements, ensuring effective communication and coordination with relevant departments and the public.

5.4.3 Post-disaster phase

To restore and rebuild the campus's built environment, it is crucial to resume normal operations promptly. This involves assessing the extent of damage caused by the disaster and developing a comprehensive recovery and rehabilitation plan. The primary focus should be on repairing and restoring infrastructure and buildings to ensure their normal functioning. Additionally, it is essential to provide psychological support and counseling to affected students and teachers, aiding them in overcoming the post-disaster phase and returning to their studies and daily lives. Furthermore, it is important to analyze the lessons learned from the post-disaster response and implement measures for improvement. Enhancing emergency response mechanisms and disaster management strategies will strengthen the overall effectiveness of the campus's resilience system.

6. Conclusion

Through the application and exploration of disaster resilience theory in the built environment of universities, this paper summarises the optimisation strategies to improve the resilience of the built environment of universities. This paper proposes an optimal construction from the three dimensions of campus resilience: ecology, facilities and technology; and establishes a governance system for the resilience of the built environment of the campus by combining the three dimensions of ecology, facilities and technology in the pre-, mid- and post-disaster phases, which provides new ideas and methods for the optimization of the built environment of universities.

This study has some limitations, as the data from the theoretical and field studies lack quantitative analysis; the study of campus built environment resilience is not independent. In the future, we will continue to optimise our research ideas and research breadth, combine subjective and objective research ideas, expand our research scope, and optimise the strategies for enhancing the resilience of the built environment of campuses, with a view to providing a reference basis for the planning and construction of resilient campuses.

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